Damping and propagation of geodesic acoustic modes in gyrokinetic simulations

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Geodesic acoustic modes (GAMs) [1] play a fundamental role in the self-regulation of turbulence in toroidal plasmas. In fact, GAM oscillations can transfer energy from the zonal flow (ZF) to the pressure perturbation [2] and can radially propagate the ZF, with important consequences on the energy transport. Moreover, GAMs are considered to be potential key players in the dynamics of the transition from low confinement (L-mode) to I- and to H-modes.

Because of the multitude of manifestation of GAMs, several of their properties are not established or not completely understood. Although most of experiments show a radial propagation toward the edge of the tokamak device, some observations show an inward radial propagation of GAMs [3]. Moreover, the role played by temperature and density gradients needs to be elucidated. In spite of the fact that a well-grounded theoretical framework exists to formulate a complete description of GAMs, only a qualitative agreement between the experimental results and the linear theory has been obtained. Thus in the last years the research has been focused in particular on the nonlinear description.

The present work, based on a theoretical and numerical gyrokinetic analysis, reveals a fundamental effect which has been neglected so far, namely that the different GAM oscillations at different radial positions lead by phase mixing [4], to the generation of higher and higher radial spectral components, which are more effectively damped. As a consequence, neglecting this effect leads to damping rates and radial propagation speeds that are largely underestimated. Analytical calculations concerning damping [5,6] and radial propagation [7] support the numerical findings. A comparison of drive and damping rates leads to a possible explanation for the disappearance of GAMs in H-mode. The propagation direction as a function of temperature gradient and electron-to-ion temperature ratio is investigated, finding a good agreement between simulations and theory. Finally, a detailed analysis of the influence of dissipative and dispersion effects on the temporal spreading of the GAM signal allows us to provide a complete new picture of the GAM behavior.

References

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